Space Pressurization: Concept and Practice

ASHRAE Distinguished Lecture Series

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ASHRAE, St. Louis Chapter
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Agenda

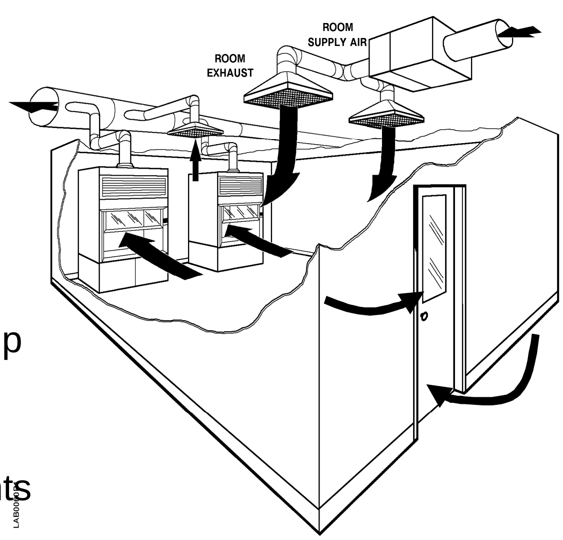
Introduction (concept, purpose, uses, scope)
Physics: Infiltration and Containment
Pressurization Methods
Design Considerations
Contaminant Control Perspective
Summary

Room Pressurization

A ventilation technology
that controls migration
of air contaminants
by inducing drafts
between spaces.

Room Pressurization

- Exhaust system removes air
- Supply system delivers less
- Room pressure is negative
- Infiltration makes up the difference
- Inward air flow contains pollutants



Introduction: Who uses it? Why?

Biological and Chemical Laboratories
- prevent spread of airborne hazards

Hospital Isolation Rooms
- protect patients and staff from germs

Hospital Pharmacies
- facilitate sterile compounding

Clean Manufacturing
- maintain product quality

Introduction: Who else uses it?

Office towers
- control smoke in a fire; maintain exit path

Any Building
- separate rest rooms from other spaces

Restaurants
- keep kitchen smells out of the dining room

Any Building
- keep unconditioned OA out of occupied spaces

These uses are out of today's scope

How is success defined?

Success is control of contaminants, not flows and pressure values

Infiltration and Containment

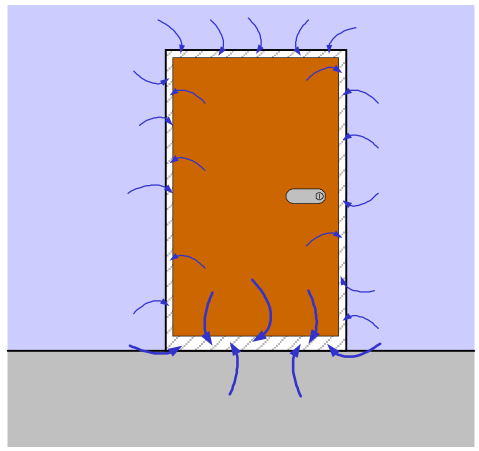
Infiltration: mechanical process
Velocity, Area, Pressure
Infiltration Curves
Importance of the Envelope
Select Pressurization Level

Infiltration Process: Pressure, Velocity, Area, Flow

Infiltration is a physical process

Pressurization is an engineered result

ASHRAE Handbook and Ventilation Manual from ACGIH model the process



Pressure vs. Velocity

Simple approach is to model the velocity with a discharge coefficient

ACGIH Industrial Ventilation: 7-3

$$v = 0.6(4000)\sqrt{\Delta P}$$

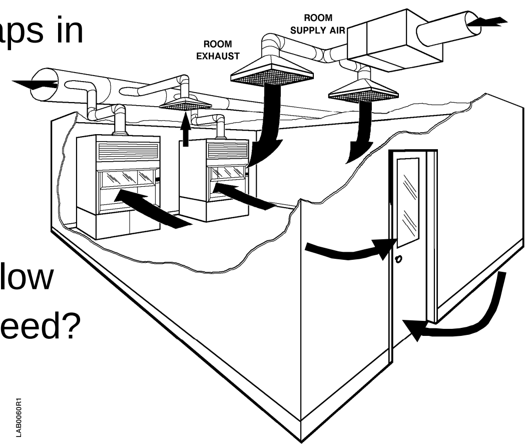
ASHRAE Fundamentals Handbook presents more complex model, but the result is nearly the same

Infiltration Model for Pressurization

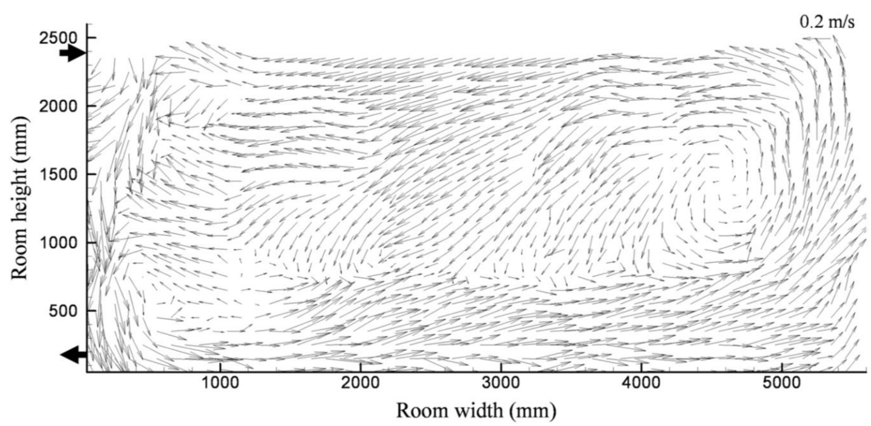
Air velocity through gaps in envelope controls contaminants

Velocity related to pressure by orifice flow

What velocity do we need?



Reality of Room Air Motion



Photograph of flow field (2D) in cross section of a room
“Particle Image Velocimetry”

Zhao L., ASHRAE Transactions, DA-07-044

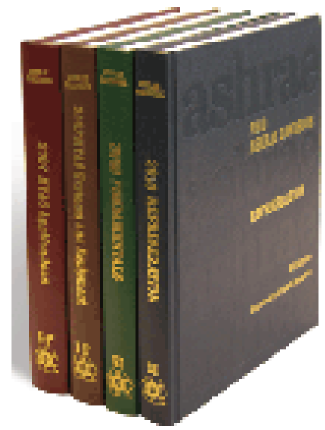
Velocity and Leakage Area

Flow is velocity times area

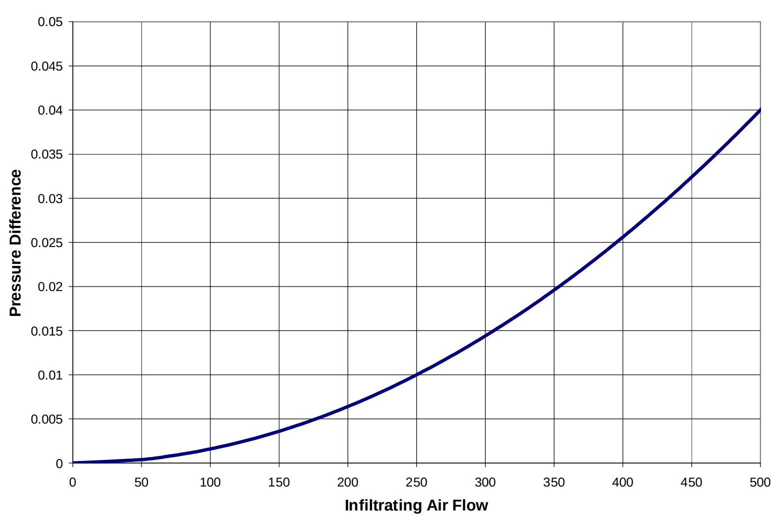
2011 ASHRAE Handbook HVAC Applications, puts it together: 53-9

$$Q = 2610A\sqrt{\Delta P}$$

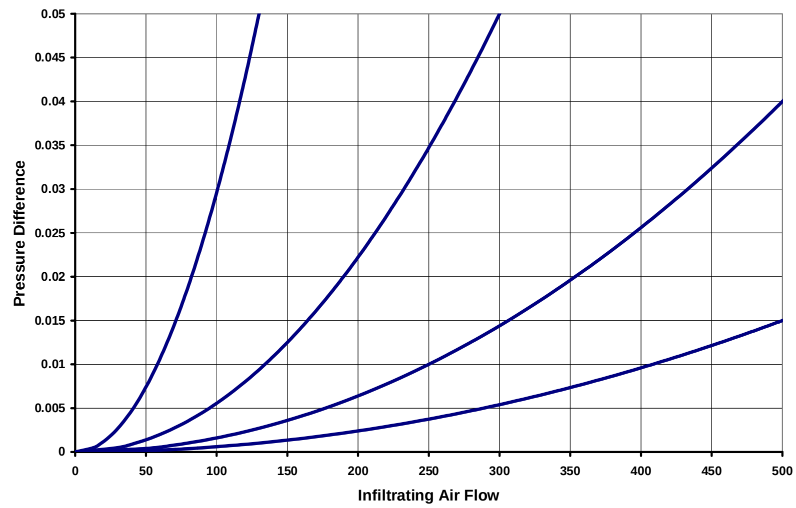
- Q = infiltration flow, cfm
- A = leakage area, sqft
- ΔP = pressure across envelope, inwc



Infiltration Curve – Pressure Difference vs. Flow



Infiltration Curves for Several Values of Leakage Area

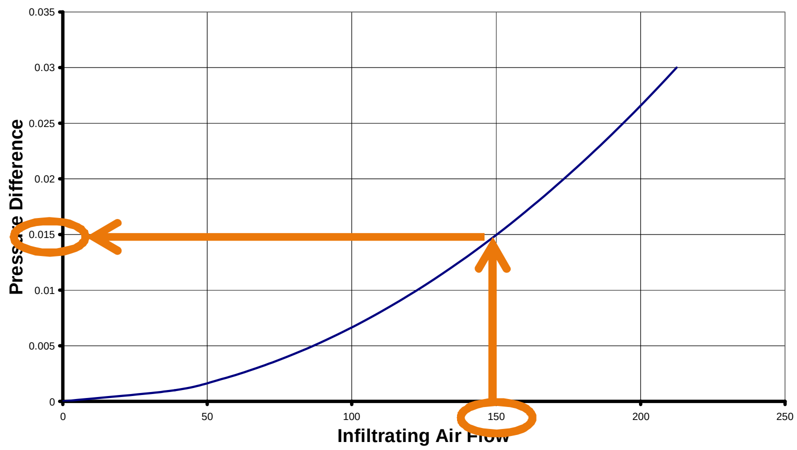


Importance of the Envelope

Leakage area is the main mechanical parameter
in the pressurization system
Like knowing the hx characteristics
to apply a heating coil
Like knowing the pipe diameter
in a hydronic system

Select Pressurization Level

Choose the flow offset
Let it determine the pressure



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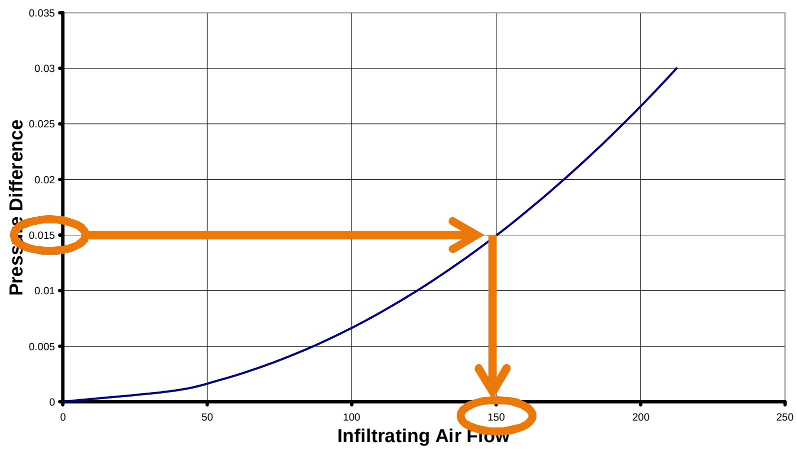


Select Pressurization Level

Different ways to express the level of pressurization
- in terms of the pressure difference
- in terms of the infiltration flow

"Specify either the pressure
or the flow offset, not both."

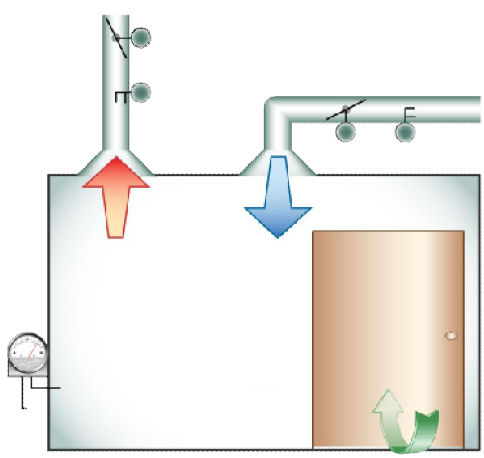
Unless you are trying to specify the envelope

Pressurization and Migration

Positive room pressure drives air and contaminants out

Negative room pressure draws air and contaminants in

Neutral room pressure exchanges air and contaminants both directions



Pressurization via HVAC

Control Methods Explained and Compared

- Differential Flow Control
- Pressure Feedback
- Cascade Control

Selecting a Pressurization Control Method

- Tightness of the Envelope
- Required Pressure Relationships

Control Methods Compared

Three widely published methods

- Space pressure feedback
- Differential flow control
- Cascade control

References:

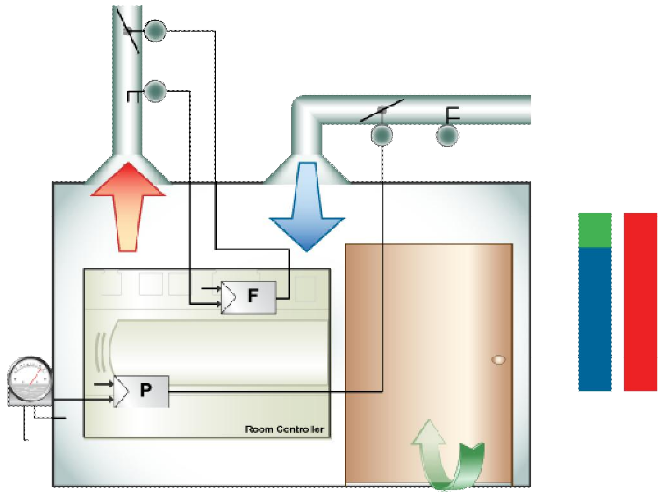
- 2011 ASHRAE Handbook, HVAC Applications. Chapter 16 Laboratory Systems
- Siemens Building Technologies: Doc #125-2412. Room Pressurization Control

Control Methods Compared

Some other ways
- Adaptive leakage model
- Trim valve

References:
- W Sun, ASHRAE Transactions, NA-04-7-2. Quantitative Multistage Pressurizations in Controlled and Critical Environments
- L. Gartner and C. Kiley, Anthology of Biosafety 2005. Animal Room Design Issues in High Containment

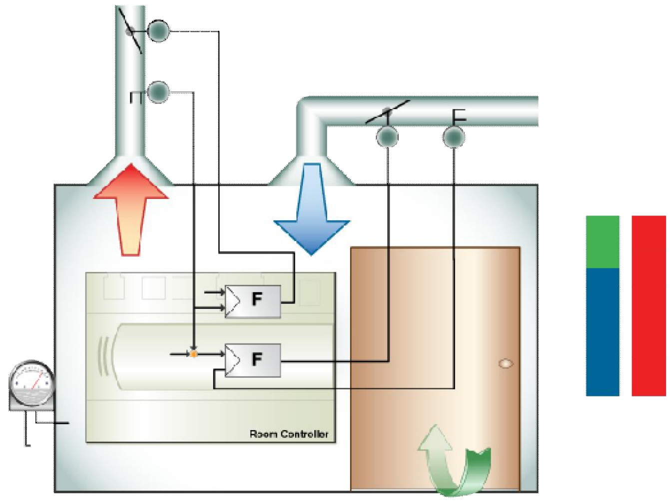
Pressure Feedback



Pressure Feedback

Measure pressure difference
across room boundary
Compare to selected setpoint
Adjust supply flow or exhaust
to maintain pressure difference

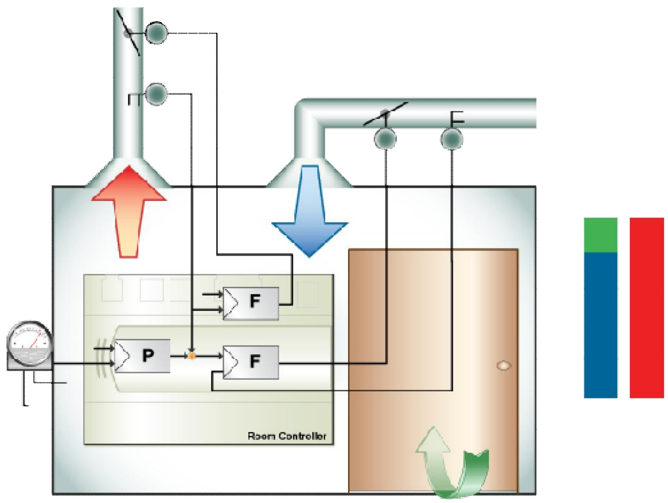
Differential Flow Control



Differential Flow Control

Carefully control air supply to room
Carefully control all exhaust from room
Enforce a difference between them
Select the size of difference
  to reliably contain pollutants

Cascade Control



Cascade Control

Has other names:

- “adaptive offset” “DP reset”

Measure pressure difference across room boundary

Compare to selected setpoint

Control supply and exhaust flow

Enforce a difference between them

Dynamically adjust flow difference to maintain the pressure setpoint

Selecting a Control Method

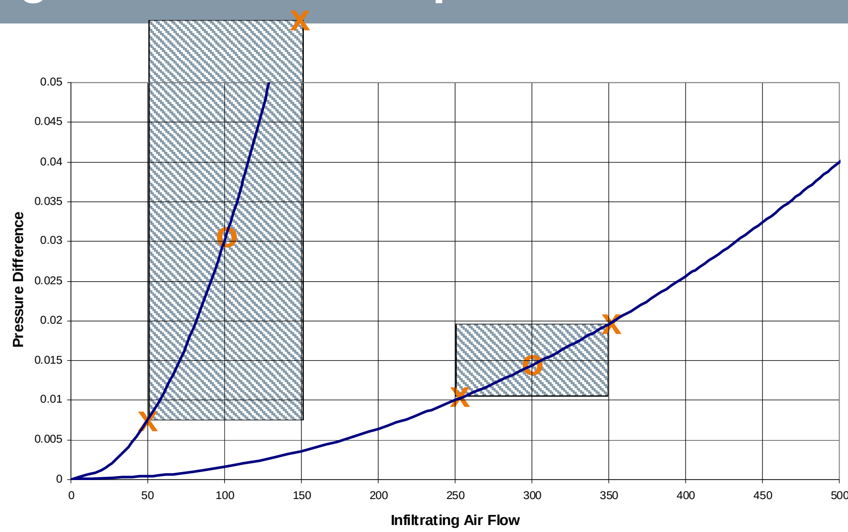
Factors affecting selection

- Tightness of envelope
- Number of pressure levels needed
- Speed of disturbances and response
- Duct conditions for flow measurement

Reference:

2011 ASHRAE Handbook – HVAC Applications, Chapter 16 - Laboratory Systems, page 16.12

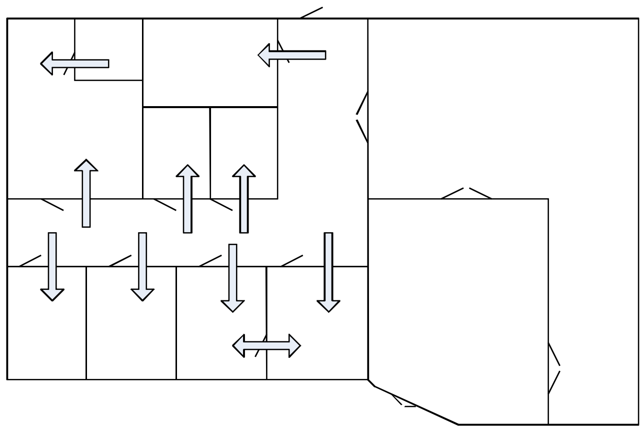
Tightness of Envelope



Number of Pressure Levels

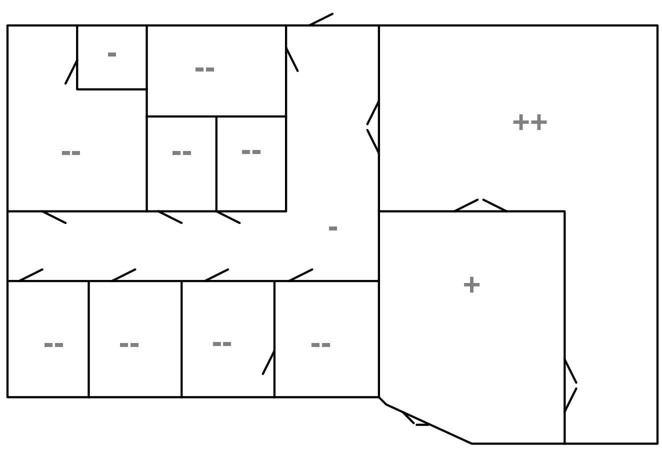
Relatively simple requirement

2-levels, OK for Differential Flow Tracking



Number of Pressure Levels

Indicate intended relative pressure levels



Design Considerations: Effect of Air Flow Errors, In and Out

Numerical illustration

	Nominal value	Error
Exhaust flow	1000	+/- 100
Supply flow	850	+/- 85
Transfer flow	150	+/- 185

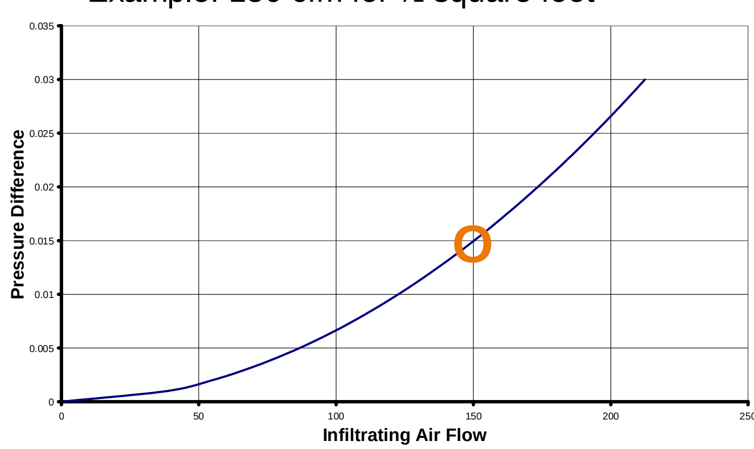
Base flow control accuracy on desired infiltration

ANSI Z9.5, Laboratory Ventilation

Select Pressurization Level

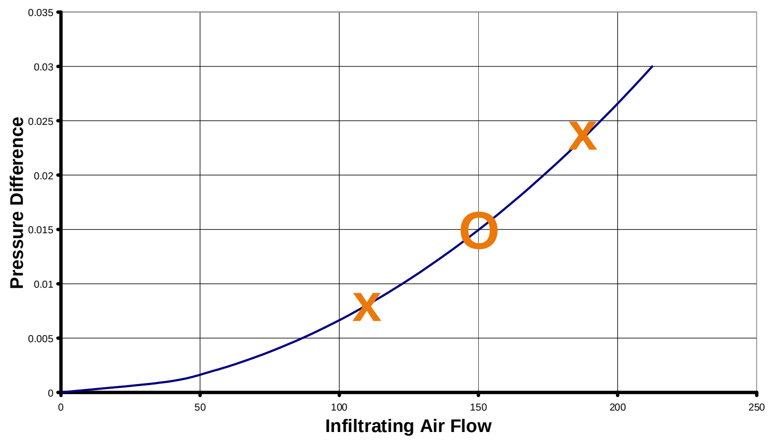
Based on leakage area

Example: 150 cfm for ½ square foot



Select Accuracy Target

Based on need to control contaminants
Not product spec's



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Derive Flow Control Accuracy

Base flow control accuracy on desired infiltration
Select allowable error on supply and exhaust
for resulting transfer accuracy

	Nominal value	Error
Exhaust flow	1000	+/- 30
Supply flow	850	+/- 30
Transfer flow	150	+/- 45

Combine errors with square root of sum of squares

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Derive Flow Control Accuracy

For VAV:

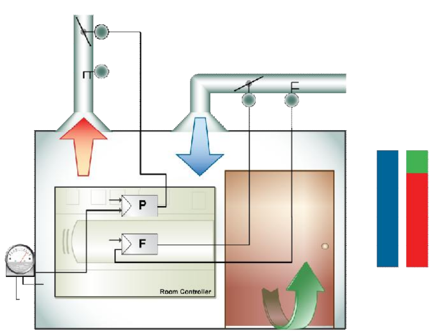
Consider accuracy across range of flow values

Pressurization specs easier to meet at low flow

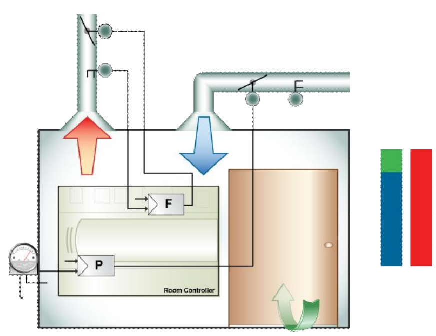
	Nominal value	Error
Exhaust flow	1000 200	+/- 30 +/- 30
Supply flow	850 50	+/- 30 +/- 30
Transfer flow	150	+/- 45

Design Considerations: Which Terminal Does Pressurization

Exhaust tracks supply



Supply tracks exhaust



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Pressurization and Contaminant Control

Success is control of contaminants, not flows and pressure values

Theory: net inward flow blocks contaminants

Research relates pressurization to contaminant control

- ASHRAE research relates pressure to clean room contamination: RP 1344 and RP 1431. W. Sun
- Bio lab experiments: Bennet, Applied Biosafety, 2005
- Isolation room experiments: C. Hayden, et al., AOEH, 1998
- Water model of isolation room: Tang, et al., PlosOne, 2013

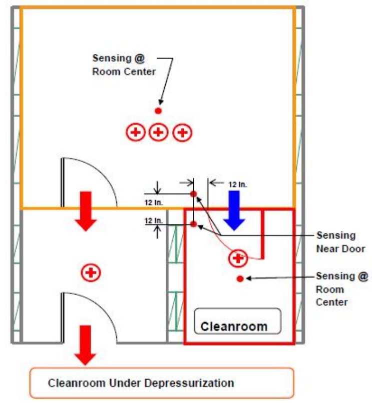
Fact: contaminants cross boundaries for many reasons

Recent Research Projects

Projects study movement of contaminants with:

- Open doors
- Moving doors
- Moving people

ASHRAE RP 1344 and 1431 measured with particle source and counter



Wei Sun, ASHRAE Research Report, RP 1344, Clean Room Pressurization Strategy Update

Recent Research Projects

Projects study movement of contaminants with:

- Open doors
- Moving doors
- Moving people

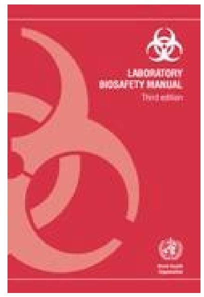
Hospital study used water tank model

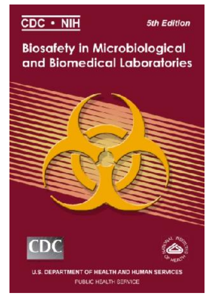
Tang JW, Nicolle A, Pantelic J, Klettner CA, Su R, et al. (2013) Different Types of Door-Opening Motions as Contributing Factors to Containment Failures in Hospital Isolation Rooms. PLoS ONE 8(6): e66663. doi:10.1371/journal.pone.0066663

Pressurization and Contaminant Control

Contaminant control can be very important or only slightly important

Biosafety standards recognize range of hazards and range of responses





Engineering and commissioning should match effort and solutions to needs

Levels of Contaminant Control

Pressurization is one tool

Physical barrier is also

- BSL 1 – Laboratories should have doors
- BSL 2 – Doors should be self-closing
- BSL 3 – Series of two self-closing doors
- BSL 4 – Airlock with air tight doors

Summary

Space pressurization: tool for contamination control, not a 'magic shield'

Envelope leakage is main mechanical parameter

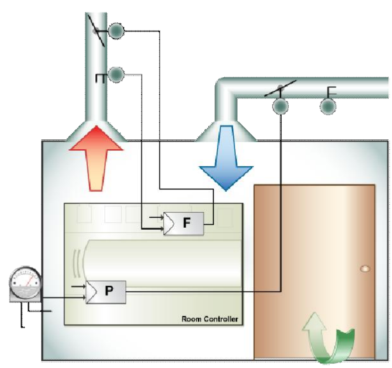
Several HVAC control methods

- Differential flow control is used most often
- Choice usually driven by envelope

Derive air flow accuracy spec from pressurization

Align engineering effort with the hazard

Thank you!
Questions?



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